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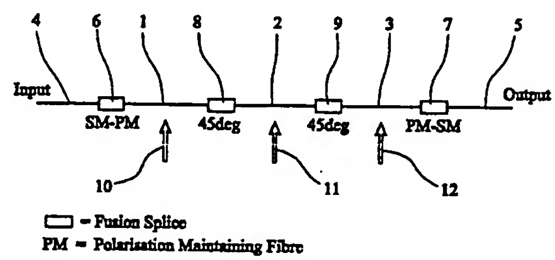
(54) Title: POLARISATION CONTROL

(57) Abstract

A polarisation controller comprises a first section (2) of polarisation maintaining optical fibre connected to a second section (1) of polarisation maintaining optical fibre. The second section is orientated such that its preferred polarisation mode axes lie at 45 degrees or 135 degrees to those of the first section.



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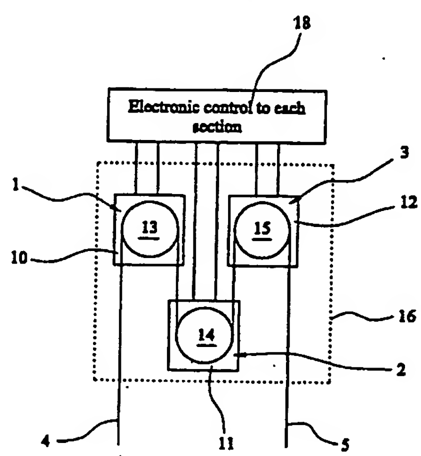

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Polarisation Control

Technical Field

The present invention in its various aspects relates to a polarisation controller and a method of controlling polarisation, and a method and apparatus for rotationally orientating longitudinally aligned optical fibres.

As used in this text, the term light covers other forms of electromagnetic radiation; however, infra-red and visible light in particular is contemplated.

Background

Control of the state of polarisation in an optical fibre system is important, in communications, test and measurement and sensing applications. It is known that the overall state of polarisation can be modified by controllers in which a series of waveplates are oriented such that their birefringent axes are oriented in the correct relative positions. Such controllers involve transforming any arbitrary state of polarisation to any desired output state of polarisation, and several methods are known to perform the transform. In optical fibre systems, a known approach is use of a quarter-half-quarter wave configuration formed by bending the optical fibre around a series of discs. This is a mechanically variable device which utilises the modification of the birefringence in a standard single mode fibre. A known alternative is to use three liquid crystal waveplates, the birefringence of which can be modified as a function of a drive voltage. The three plates are in series, oriented at 45 degrees sequentially. The major problem with this known form of device is that it is not completely compatible with the fibre technology, and consequential losses and degrading of light signals occur.

Statements of Invention

The present invention in its first aspect provides a polarisation controller comprising a first section of polarisation maintaining optical fibre connected to a second section of polarisation maintaining optical fibre, the second section being orientated such that its preferred polarisation mode axes lie at 45 degrees or 135 degrees to those of the first section.

Preferably, the polarisation controller further comprises a further section of polarisation maintaining optical fibre connected to the first section, the further section being orientated such that its preferred polarisation mode axes lie at 45 degrees or 135 degrees to those of the first section. Preferably, the polarisation controller alternatively comprises a polariser having an output polarisation aligned at 45° to the preferred polarisation of the first section, the polariser being connected to the first section. Preferably the polariser is a linear polariser.

Preferably, the first section, the second section (and the further section if present) are each adjustable in phase difference between light wave components in their two polarisation modes. This can be considered as each section functioning as an adjustable waveplate. The phase differences are adjusted by temperature control of the two or more sections so as to control the state of polarisation of transmitted light therethrough. Preferably each of the two or more sections is attached to a corresponding heater means for selectable heating. Preferably the temperature of each of the two or more sections is adjustable within a temperature range to enable any selected state of polarisation to be provided as an output end of the polarisation controller for any state of polarisation at the polarisation control input end.

Preferably the polarisation controller is connected at its input end and output end to respective single mode optical fibres.

Preferably the output light from the polarisation controller is sampled using a directional coupler connected to a polarisation analyser, the polarisation analyser being operative for servo-control of the polarisation controller, in particular by temperature control of the sections.

Preferably the first section and the second section are connected via an intermediate section of polarisation maintaining optical fibre orientated so that its preferred polarisation mode axes are at 90 degrees to those of the first section. This is, in particular, to ensure correct functioning of the polarisation controller with light from a low coherence source.

Preferably, the further section and the first section are connected via a second intermediate section of polarisation maintaining optical fibre orientated so that its preferred polarisation mode axes are at 90 degrees to those of the further section.

Preferably the second section is connected to the polarisation controller output via a third section of polarisation maintaining optical fibre orientated so that its preferred polarisation mode axes are at 90 degrees to those of the first section.

Preferably the sections of the polarisation controller are

connected by fusion splicing.

The present invention in its first aspect also relates to corresponding methods of controlling polarisation.

It will be seen that preferred embodiments of the present invention in its first aspect advantageously provide a fibre compatible, electronically addressed polarisation controller.

The present invention in its second aspect relates to a method of rotationally orientating longitudinally-aligned optical fibres by:

(1) passing polarised light through the fibres,

(2) rotating one of the fibres relative to the other fibre,

(3) rotating a polariser into which the light from the fibres is fed to determine maximum and minimum transmitted power levels,

(4) repeating steps (2) and (3) as necessary until the desired power level difference is obtained.

The present invention in its second aspect also relates to apparatus for rotationally orientating longitudinally-aligned optical fibres comprising

(a) a first polariser operative to transmit polarised light into the fibres,

(b) rotation means to state one of the fibres relative to the other

(c) a transmitted signal analyser comprising a rotating polariser and optical power detector, and operate to determine maximum and minimum transmitted power levels.

Preferably the two fibres are fusion spliced after being placed in the desired rotational orientation. The means for rotating the fibre is preferably a fusion splicer with rotating chucks.

A maximum difference between maximum and minimum detected power levels indicates 0 degrees or 90 degrees relative orientation. A minimum difference between maximum and minimum detected power levels indicates 45 degrees relative orientation.

Preferably light is passed into the fibres from an optical source via a depolariser to minimise residual polarisation before transmission into the first polariser.

Preferably the transmitted signal analyser also comprises an optical collimator.

The present invention in its second aspect also relates to a corresponding method and corresponding apparatus for orientating and fusion-splicing the fibres.

The present invention in its third aspect relates to an optical fibre splicer comprising a cleave-tool, fusion electrodes and a hinged arm to which the fibre is held in use, the cleave-tool being in a predetermined position relative to the fusion electrodes, and the arms being moveable between a first position for cleaving by the cleave tool and a second position for splicing by the fusion electrodes.

Preferably, the splicer includes a rotator operative to controllably rotate a fibre section after cleaving relative to the central longitudinal axis of the fibre

section.

The present invention in its third aspect also relates to a method of using an optical fibre splicer comprising a cleave-tool, fusion electrodes and a hinged arm to which the fibre is held in use, the cleave-tool being in a predetermined position relative to the fusion electrodes, and the arms being moveable between a first position for cleaving by the cleave tool and a second position for splicing by the fusion electrodes, by mounting an optical fibre on the hinged arm, moving the hinged arm to a position for cleaving the fibre, cleaving the fibre into two fibre sections using the cleave tool, moving the hinged arm to a position for splicing the two fibre sections, and using the fusion electrodes to splice the two fibre sections.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will now be described by way of example and with reference to the drawings in which:

Figure 1a is a schematic side view of a first polarisation controller, one section of optical fibre being aligned with its preferred axes at 45° to its preceding neighbour,

Figure 1b is a schematic top view of the first polarisation controller,

Figure 2 is a schematic side view of a second polarisation controller including two optical fibre sections each aligned with their preferred axes at 45° to the preceding section,

Figure 4 is a schematic top view of a further polarisation controller including a control loop, and

Figure 5 is a schematic diagram of apparatus for splicing (joining) optical fibre sections at predetermined relative alignment of their preferred axes.

Figure 6 is a schematic diagram of a further splicer.

Polarisation maintaining optical fibre is produced by creating a high birefringence within the fibre. Two preferential, effectively linear polarisation axes are created, by either producing an elliptical shaped core or producing stress members in the cladding material which modify the core refractive index through the applied stress. The two orthogonal linear polarisation modes propagate at different velocities; therefore an optical signal launched onto both axes simultaneously will experience a phase shift between the polarisation modes along the fibre. The beat length of the fibre for a given wavelength is defined as the length of fibre over which the relative paths of the two polarisation modes has slipped by 2ō radians. The polarisation maintaining fibre is therefore functioning as a waveplate the relative phase value of which for a specific wavelength is defined by the fibre length and the birefringence (beat length). The parameters of the fibre can be modified by, mechanically stretching or compressing or by varying the temperature; therefore its waveplate functioning (relative phase between propagation modes) is variable over a full range by changing the fibre mechanically or thermally.

Electronically Controlled Polarisation Controller

As shown in Figure 1a, a first polarisation controller

is constructed by fusion-splicing three lengths 1,2,3 of high birefringence (polarisation maintaining) optical fibre, with length 2 and length 3 aligned with axes at 45° to the preceding length (length 1 and length 2 respectively). The three fibre lengths 1,2,3 are connected with their respective preferential axes at 45°. Independent parameter adjustment of each of the sections, e.g. as described below, provides a polarisation controller capable of generating any state of polarisation from an arbitrary input state of polarisation.

Lengths 4, 5 of standard single mode optical fibre SM are fusion-spliced to input end 6 and output end 7 of the spliced polarisation maintaining fibre sections 1,2,3. Splice regions 6,7,8,9 are protected by short lengths of silica tubing or similar mechanically protecting device. Each polarisation maintaining fibre length 1,2,3 is attached to a corresponding heater element 10,11,12, which is a fully controlled heater circuit with integral feedback, or, alternatively some form of resistive heater. The temperature of each of the heater elements 10, 11, 12 is controlled by varying an external resistance (not shown).

As shown in Fig. 1b, the fibre lengths 1,23 are coiled and contained within a thin metal 'oven' 13,14,15 or, alternatively, wound around a metal disc (not shown). The oven 13, 14, 15 or disc is heated by the heating elements 10,11,12. The change in temperature is such that at least one full optical phase cycle difference between the two polarisation modes can be induced, and the fibre length and temperature range are selected to accommodate this requirement. The whole unit 16 is thermally insulated from the environment and each fibre length 1,2,3 is insulated from each other. Varying the temperature of each of the

lengths 1,2,3 through external electronic means 18 allows any state of polarisation to be realised at the output 5 from an arbitrary state of polarisation at the input 4.

The polarisation controller described has relatively long fibre lengths which cause long differential time delays between the polarisation modes. The reason is to obtain the necessary phase change with a moderate temperature change. However, if the delay is longer than the coherence time of the source the controller will not function correctly. This problem is overcome by the polarisation controller for a low coherence source which is described next.

Polarisation Controller with Low Coherence Source

As shown in Fig. 2, this problem is overcome by 'matching' the pathlengths for each section. The resulting polarisation controller has six sections 1',2',3',4',5',6'. The second section 2' is equal in length to the first section 1', and fusion spliced with the fibre axes at 90°, the fourth section 4' is equal in length to the third section 3' and fusion spliced with the fibre axes at 90°, and the sixth section 6' is equal in length to the fifth section 5' and fusion spliced with the fibre axes at 90°.

The third section 3'is second spliced to section 2' with the axes at 45° and the fifth section 5' is fusion spliced to the fourth section 4' with the axes at 45°. The first, third and fifth sections 1', 3', 5' are heated as described above and the second, fourth and sixth sections 2', 4', 6' are thermally insulated from the heated sections 1',3',5' and the external environment.

Polarisation Controller with Defined input polarisation

An alternative version of the polarisation controller

is shown in Fig. 3. This includes a linear polariser 20 at the input 22 (which is a polarisation maintaining optical fibre but in an alternative embodiment is a single mode fibre) such that the output polarisation of the linear polariser is aligned at 45° to the axes of the section of the high birefringence fibre. A section 2" of high birefringence fibre is fusion spliced to the first section 1". Controlling the temperature of the two sections 1", 2" any state of polarisation can be defined at the output 24. The linear polariser 20 is of known type or can be an all-fibre device spliced at 45° to the first section 1".

One application is to send an output signal from an optical source such as a semiconductor or fibre laser into the high birefringence fibre such that the polarisation is aligned along one axis. This polarisation controller provides a selectable output state of polarisation by modifying the temperature of the two sections 1", 2". With the source output aligned on the axis the linear polariser

20 is optional, but serves to improve the polarisation extinction ratio achievable from the polarisation controller. The polarisation controller can be controlled electronically and automatically to select one or more polarisation states.

An alternative application is with a depolarised or randomly polarised light signal input to the polarisation controller and thereby any output polarisation state can be achieved. The inherent minimum loss is -3dB.

An alternative form (not shown) of this polarisation controller is basically as described above and shown in Frame 3; but including matching fibre lengths at 90° to each section 1",2" for use with low coherence sources.

The polarisation controller described above and shown in Fig. 3, or in its alternative form described in the paragraph immediately above, is usable in reverse to maximise the polarisation output in the defined linear polarisation state for any arbitrary input state of polarisation.

Control Loop

As shown in fig. 4, part of the signal output from a polarisation controller, such as the polarisation controller described with reference to Fig. 1b, can be tapped off, by a directional coupler 26 of low coupling ratio for example, and passed through a polarisation analyser 28 consisting of a polariser or series of polarisers to monitor the level of optical power. The optical power level can be used by the polarisation analyser to create a control signal 30 to automatically maintain the required state of polarisation at the output of the polarisation controller.

Methods of Fabrication

In making the polarisation controllers, the relative angles of the axes of the high birefringence fibre are determined and where necessary adjusted prior to fusion splicing.

The apparatus to do this is shown in Fig. 5 and consists of:

* A low coherence optical source 32 which has a wavelength such the first fibre 34 propagates the light with a single mode. The source output power level can be adjusted, the temperature is controlled to maintain a stable power output and the output power can be modulated.
* A depolariser 36 operative to minimise the residual polarisation of the optical signal.
* A linear polariser 38 to define a good quality single polarisation.
* The first fibre 34 and second fibre 40 to be aligned relative to one another, mounted in a known fusion splicer 42 with rotation chucks (not shown) to rotate the fibres.
* A fibre holder (not shown) and optical collimator 44.
* A bulk polariser 46, typically a crystal polariser which can be rotated through 360°.
* A detector 48 with a detection surface of a large area light much greater than the beam diameter.
* A voltmeter or lock-in amplifier and a modulation unit (not shown) between the detector 48 and optical source 32.

Fibre Alignment Method 1

To align and fuse the two fibre lengths for 32, 40, the first polariser 38 is aligned with the axis of the first fibre length 32. The two fibres lengths 32, 40 to be aligned are mechanically adjusted to allow maximum power to pass through. The collimated beam from collimator 44 passes through the rotatable polariser 46 to the detector

48. One fibre length 32, 40 is rotated in the splicer 42, the throughput power maximised and the rotating output polariser 46 rotated to find the highest throughput power and the lowest throughput power. When the difference between the power levels is maximum the axes of the fibre lengths 32, 40 are aligned at 0° or 90°. When the difference between the power levels is minimum (zero) the axes are aligned at 45°. The process of rotating in the splicer 42 and measuring the two power levels is continued until the required power difference is obtained. The fibre lengths 32, 40 are then fused together.

Fibre alignment method 2

The method described above to align the fibres at 45° is only effective for one alignment. In the case where multiple fibres are to be spliced or 90° splicing is required an alternative method is used as follows. The apparatus used is basically as described above with reference to figure 5, but with a modified splicer 42' as described below and without the rotating polariser 46.

A continuous length of polarisation maintaining fibre is placed in supports of the fusion splicer 42' which is shown in Figure 6 which has precision rotation chucks incorporated. Light is transmitted into the fibre and the power level detected at the output optical power detector 48.

A single fibre is attached by means of spring clamps 50, 52 either side of fusion electrodes of the splicer 42' to a moveable arm 56. The arm swings the fibre from its position in the splicer 42' to a cleave tool 58, set-up such that the cleave edge 60 is aligned with the fusion electrodes 54.

The fibre is cleaved and swung back on the movable arm into the splicer 42'. Each of the two sections of the now

cleaved fibre is still mounted into a respective splicer clamp 50, 52. Two fibre sections are thus cleaved and set in the splicer without changing the relative orientation of the fibre axes, in this case 0°.

One of the fibre sections is then rotated to the required angle by reading the angular rotation of a precision rotator which is part of one clamp 52 the splicer 42. Once the angle has been set, the power throughput of the fibre is maximised by adjusting the relative positions of the fibre sections and then they are fused.

The fused region can then be protected with silica tube or similar, and the fibre is moved along the splicer by any required length and the process repeated for as many times as necessary to form the device.

CLAIMS:

1. A polarisation controller comprising a first section (2) of polarisation maintaining optical fibre connected to a second section (1) of polarisation maintaining optical fibre, the second section being orientated such that its preferred polarisation mode axes lie at 45 degrees or 135 degrees to those of the first section.

2. A polarisation controller according to claim 1, further comprising a further section (3) of polarisation maintaining optical fibre connected to the first section (2), the further section (3) being orientated such that its preferred polarisation mode axes lie at 45 degrees or 135 degrees to those of the first section (2).

3. A polarisation controller according to claim 1, further comprising a polariser (20) having an output polarisation aligned at 45° to the preferred polarisation of the first section (1″), the polariser being connected to the first section (1″).

4. A polarisation controller according to claim 3, in which the polariser (20) is a linear polariser.

5. A polarisation controller according to any preceding claim, in which the first section (2), the second section (1) (and the further section (3) if present) are each adjustable in phase difference between light wave components in their two polarisation modes.

6. A polarisation controller according to claim 5, in which the phase differences are adjusted by temperature control of the first section, the second section (and the further section if present) so as to control the state of

polarisation of transmitted light therethrough.

7. A polarisation controller according to claim 6, in which each of the first section, the second section (and the further section if present) is attached to a corresponding heater means (10, 11, 12, 13, 14, 15) for selectable heating.

8. A polarisation controller according to claim 5 or claim 6, in which the temperature of each of the first section, the second section (and the further section if present) is adjustable within a temperature range to enable any selected state of polarisation to be provided at an output end (5) of the polarisation controller for any state of polarisation at the polarisation controller input end (4).

9. A polarisation controller according to any preceding claim, connected at its input end (4) and output end (5) to respective single mode optical fibres.

10. A polarisation controller according to any preceding claim, in which in use the output light from the polarisation controller is sampled using a directional coupler (26) connected to a polarisation analyser (28), the polarisation analyser being operative for servo-control (30) of the polarisation controller.

11. A polarisation controller according to claim 10, in which in use the servo-control is by temperature control of the sections.

12. A polarisation controller according to any preceding claim, in which the first section (2') and the second section (3') are connected via an intermediate section of

polarisation maintaining optical fibre orientated so that its preferred polarisation mode axes are at 90 degrees to those of the first section (2').

13. A polarisation controller according to claim 2 or any claim dependent on claim 2 in which the further section (1') and the first section (2') are connected via a second intermediate section of polarisation maintaining optical fibre orientated so that its preferred polarisation mode axes are at 90 degrees to those of the further section (1').

14. A polarisation controller according to any preceding claim, in which the second section (3') is connected to the polarisation controller output (5) via a third section of polarisation maintaining optical fibre orientated so that its preferred polarisation mode axes are at 90 degrees to those of the first section (2').

15. A polarisation controller according to any preceding claim, in which the sections of optical fibre are connected by fusion splicing.

16. A method of controlling polarisation of light being transmitted using a first section (2) of polarisation maintaining optical fibre connected to a second section (1) of polarisation maintaining optical fibre, the second section being orientated such that its preferred polarisation mode axes lie at 45 degrees or 135 degrees to those of the first section.

17. A method of rotationally orientating longitudinally-aligned optical fibres by:

(1) passing polarised light through the fibres,

(2) rotating one of the fibres relative to the other fibre,

(3) rotating a polariser into which the light from the fibres is fed to determine maximum and minimum transmitted power levels,

(4) repeating steps (2) and (3) as necessary until obtained.

18. A method according to claim 17, in which the two fibres are fusion spliced after being placed in the desired rotational orientation.

19. A method according to claim 17 or claim 18, in which the fibre is rotated using a fusion splicer with rotating chucks.

20. A method according to any of claims 17 to 19, in which a maximum difference between maximum and minimum detected power levels indicates 0 degrees or 90 degrees relative orientation of the fibres, and a minimum difference between maximum and minimum detected power levels indicates 45 degrees relative orientation of the fibres.

21. A method according to any of claims 17 to 20, in which light is passed from an optical source via a depolariser so as to minimise residual polarisation before transmission into the first polariser.

22. A method of joining longitudinal-aligned optical fibres by rotationally orientating the fibres in accordance with any of claims 17 to 21 and then fusion splicing the fibres.

23. Apparatus for rotationally orientating longitudinally-

aligned optical fibres comprising

(a) a first polariser (38) operative to transmit polarised light into the fibres,

(b) rotation means (42) to rotate one of the fibres relative to the other

(c) a transmitted signal analyser (44, 46, 48) comprising a rotating polariser (46) and optical power detector (48), and operate to determine maximum and minimum transmitted power levels.

24. Apparatus according to claim 23, in which the rotation means comprises a fusion splicer with rotating chucks.

25. Apparatus according to claim 23 or claim 24, further comprising an optical source (32) connected via a depolariser (36) to the first polariser (38), the depolariser being operative to reduce residual polarisation before tranmission into the first polariser.

26. Apparatus according to any of claims 23 to 25, in which the transmitted signal analyser also comprises an optical collimator (44).

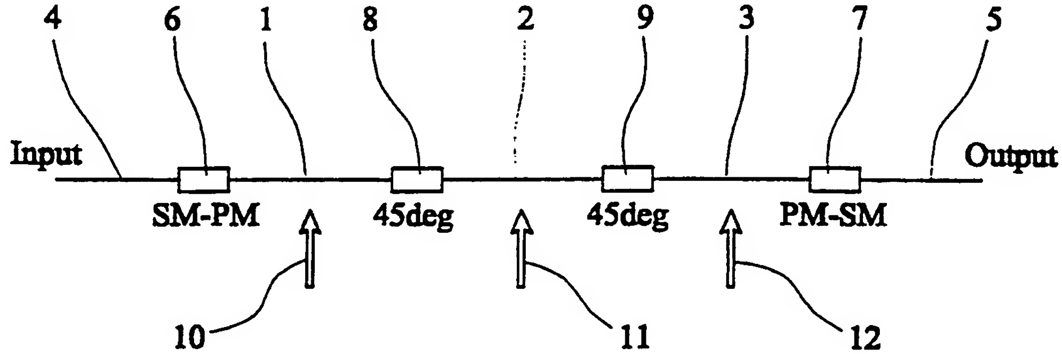
27. Apparatus for joining optical fibres comprising apparatus for rotationally orientating longitudinally-aligned optical fibres according to any of claims 23 to 26, and means to fusion-splice the fibres.

28. An optical fibre splicer (42') comprising a cleave-tool (58), fusion electrodes (54) and a hinged arm (56) to which the fibre is held in use, the cleave-tool being in a predetermined position relative to the fusion electrodes, and the arms being moveable between a first position for

cleaving by the cleave tool and a second position for splicing by the fusion electrodes.

29. An optical fibre splicer according to claim 28 including a rotator operative to controllably rotate a fibre section after cleaving relative to the central longitudinal axis of the fibre section.

30. A method of using an optical fibre splicer (42') comprising a cleave-tool (58), fusion electrodes (54) and a hinged arm (56) to which the fibre is held in use, the cleave-tool (58) being in a predetermined position relative to the fusion electrodes (54), and the arms being moveable between a first position for cleaving by the cleave tool and a second position for splicing by the fusion electrodes, by mounting an optical fibre on the hinged arm (56), moving the hinged arm to a position for cleaving the fibre, cleaving the fibre into two fibre sections using the cleave tool (58), moving the hinged arm to a position for splicing the two fibre sections, and using the fusion electrodes (54) to splice the two fibre sections.



▭ = Fusion Splice
PM = Polarisation Maintaining Fibre

FIG. 1a

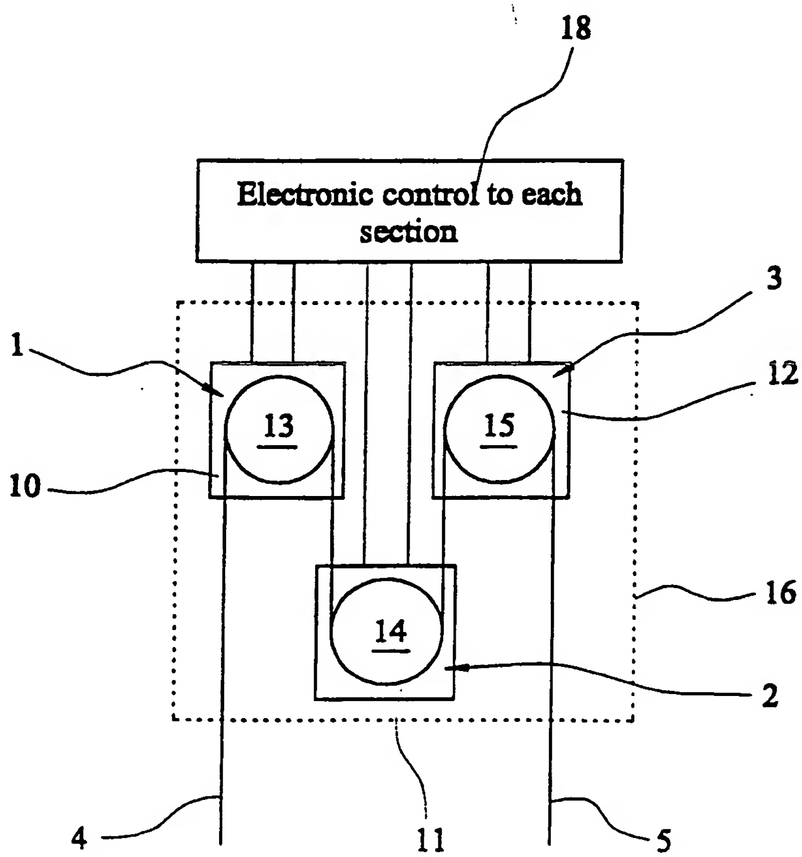


FIG. 1b

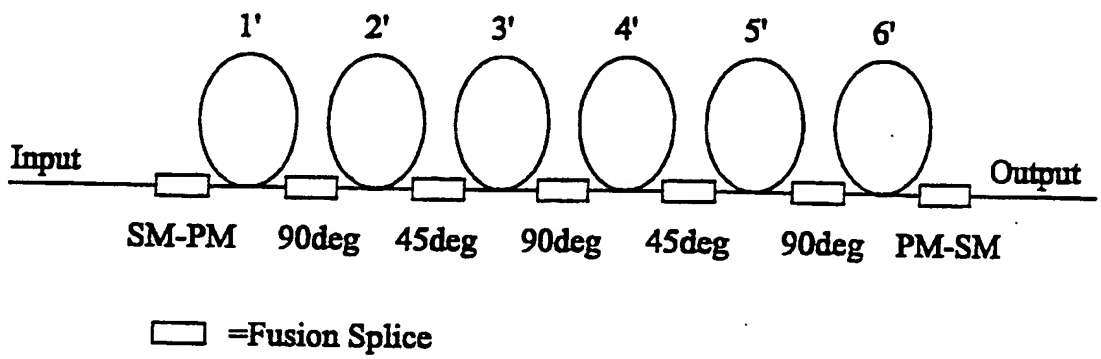

1'
2'
3'
4'
5'
6'
Input
Output
SM-PM
90deg
45deg
90deg
45deg
90deg
PM-SM
=Fusion Splice

FIG. 2

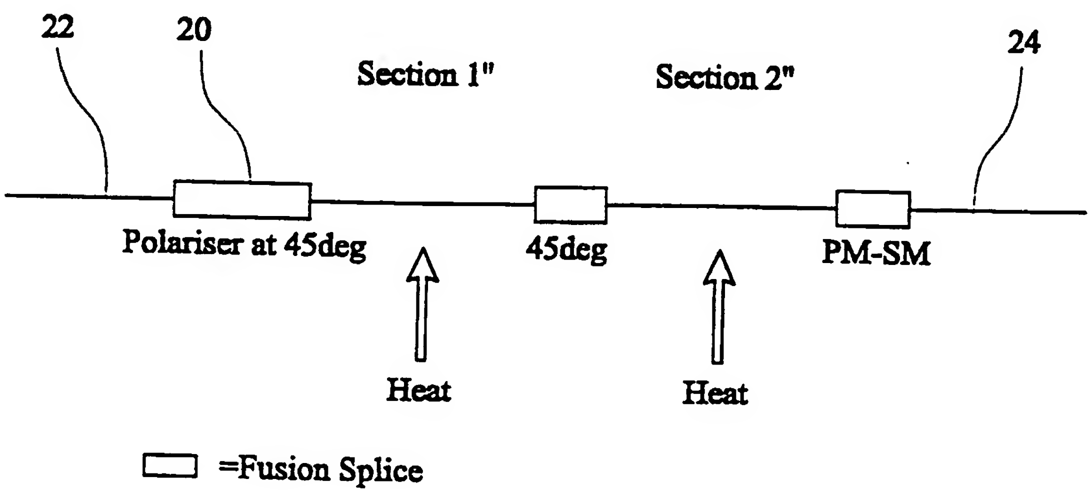

22
20
Section 1"
Section 2"
24
Polariser at 45deg
45deg
PM-SM
Heat
Heat
=Fusion Splice

FIG. 3

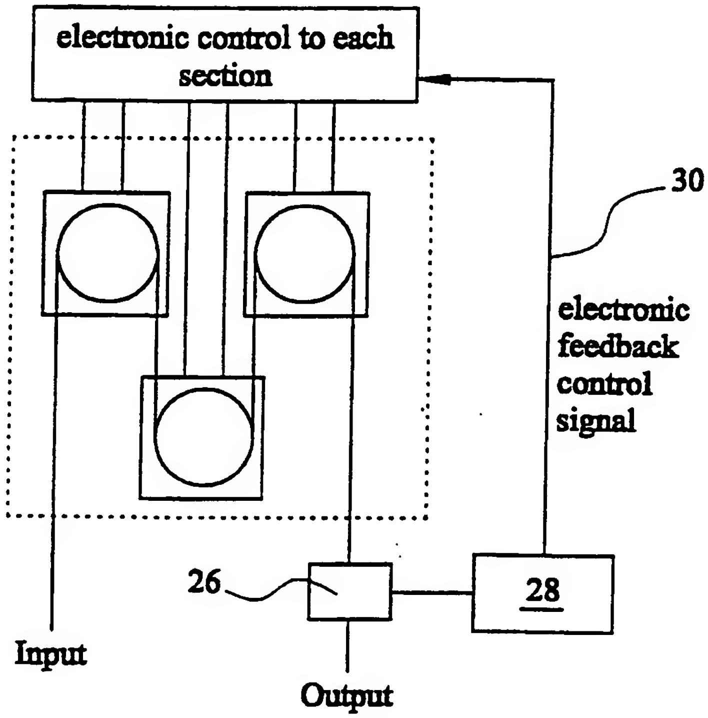

electronic control to each section
30
electronic feedback control signal
26
28
Input
Output

FIG. 4

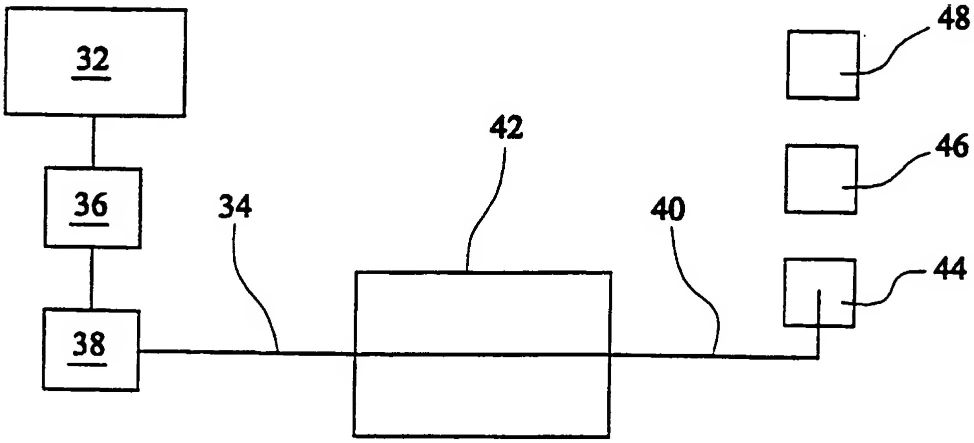

32
36
38
34
42
40
48
46
44

FIG. 5

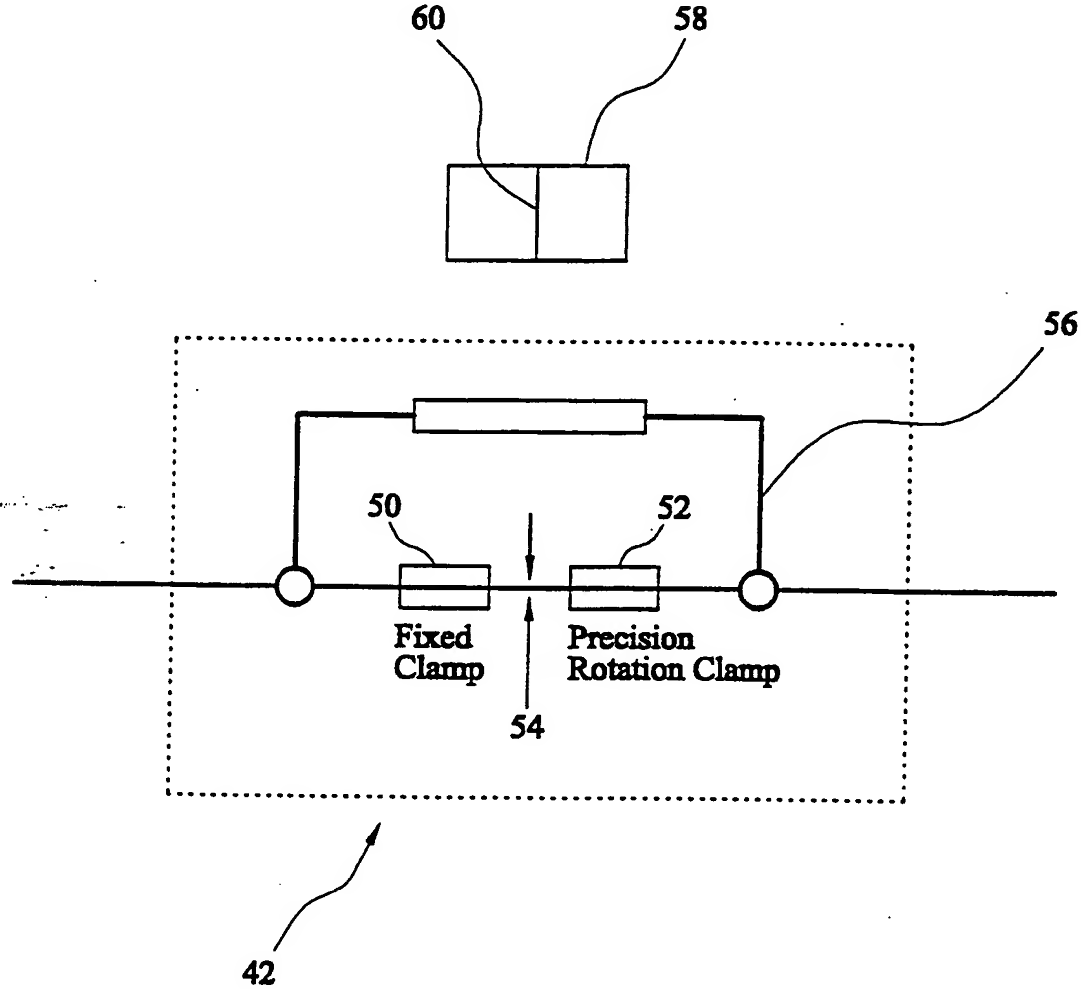


FIG. 6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/00555

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02B6/27 G02F1/01

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G02B G02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 633 959 A (NIKI SHOJI ET AL) 27 May 1997 (1997-05-27) abstract; figures 4,13,18 column 2, line 45 - line 54 column 4, line 31 -column 5, line 5 column 6, line 58 -column 7, line 10 column 11, line 35 - line 59 column 14, line 53 - line 61 column 15, line 22 - line 38 column 15, line 50 - line 52	1-5, 9-18,20, 22,23,27
Y		6-8

	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 May 2000	29.06.00

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Jakober, F

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Form PCT/ISA/210 (second sheet) (July 1992)

International Application No
PCT/GB 00/00555

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 42 23 740 A (TELDIX GMBH) 20 January 1994 (1994-01-20) abstract; figures 2,3 column 1, line 37 - line 40 column 1, line 65 -column 2, line 7 column 2, line 34 - line 41 claim 1	1,5,9, 15,16, 18,22, 23,27
X	EP 0 522 843 A (SUMITOMO ELECTRIC INDUSTRIES) 13 January 1993 (1993-01-13) abstract; figures 3,5,6,8,12,19 page 11, line 49 -page 13, line 19	1-4,9, 10, 12-18, 20-23, 25,27
Y	PATENT ABSTRACTS OF JAPAN vol. 009, no. 086 (P-349), 16 April 1985 (1985-04-16) & JP 59 216128 A (NIPPON DENSHIN DENWA KOSHA), 6 December 1984 (1984-12-06) abstract	6-8
X	US 4 572 608 A (MOCHIZUKI KIYOFUMI ET AL) 25 February 1986 (1986-02-25) the whole document	1,16,17, 22,23,27
A	WO 98 53352 A (DONAM SYSTEMS INC ;KIM YOUNG KIE (KR); YEO YOUNG BAE (KR); KIM BYO) 26 November 1998 (1998-11-26) the whole document	1-27
A	US 4 606 605 A (ASHKIN ARTHUR ET AL) 19 August 1986 (1986-08-19) the whole document	1-27

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB 00/00555

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-27

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International Application No. PCT/GB 00/00555

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210
1. Claims: 1-27 Polarization controler and method for making the same 2. Claims: 28-30 Splicing tool

TERNATIONAL SEARCH REPORT

Information on patent family members

Inte al Application No
. T/GB 00/00555

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